Claims

1. A device comprising:

a nanotube having a substantially hollow cylindrical shape, wherein said nanotube has an exterior and interior cylindrical surfaces, said exterior cylindrical surface has a diameter that is less than one micron, said nanotube has two ends, and a length between the two ends measured in a direction perpendicular to the diameter; and

a magnetic nanoparticle that is attached to the exterior cylindrical surface of the nanotube, the magnetic nanoparticle having a longest dimension that is less than one micron.

2. The device of claim 1, further comprising a plurality of magnetic nanoparticles that are that are attached to the exterior cylindrical surface of the nanotube.

3. The device of claim 2, wherein the magnetic nanoparticles are superparamagnetic.

4. The device of claim 1, wherein the nanoparticle contains an element selected from the group consisting of cobalt, nickel and iron.

5. The device of claim 1, wherein the nanoparticle is attached to the nanotube by an electrostatic or hydrophobic interaction with a carbonyl, carboxyl, hydroxyl or sulfate functional group.

6. A transistor comprising:

a source;

a drain;

a gate;

a channel, the channel including a nanotube having a substantially hollow cylindrical shape, wherein said nanotube has an exterior and interior cylindrical surfaces, said exterior cylindrical surface has a diameter that is less than one micron, said nanotube has two ends, and a length between the two ends measured in a direction perpendicular to the diameter, and the nanotube is disposed between

the source and the drain; and is substantially aligned along the shortest distance between the source and the drain, and the nanotube has at least one magnetic nanoparticle attached to the exterior cylindrical surface.

7. A sensor device for detecting biological or chemical molecules comprising:

a plurality of conductive electrodes;

a single or plurality of nanotube channels connecting the electrodes, wherein the nanotubes having substantially hollow cylindrical shape, wherein said nanotube has an exterior and interior cylindrical surfaces, said exterior cylindrical surface has a diameter that is less than one micron, said nanotube has two ends, and a length between the two ends measured in a direction perpendicular to the diameter, said nanotube channels are substantially aligned with each other and with respect to the edges of the electrodes, and each nanotube has at least one magnetic nanoparticle attached to the exterior cylindrical surface.

8. An electronic apparatus comprising

a plurality of electronic devices; and

a plurality of conductive interconnects that are connected between the electronic devices, each of the conductive interconnects including a nanotube having a substantially hollow cylindrical shape, wherein said nanotube has an exterior and interior cylindrical surfaces, said exterior cylindrical surface has a diameter that is less than one micron, said nanotube has two ends, and a length between the two ends measured in a direction perpendicular to the diameter, the length being greater than the diameter, and each nanotube has at least one magnetic nanoparticle attached to the exterior cylindrical surface.

9. The electronic apparatus of claim 8, wherein the electronic devices include a magnetic random access memory (MRAM) cell.

ABSTRACT OF THE DISCLOSURE

[0035] Present invention provides enabling methods of integrating novel nanotube elements into semiconductor devices, such as transistor containing electronic device. This is done in a series of process steps, which consist of attaching magnetic nanoparticles to nanotubes, tailoring magnetic nanotubes of selected size (diameter and length), filtration of nanotube to pre-determined sizes, preparing nanotube precursor in aqueous chemicals to form colloidal solutions of proper concentration, dispersing nanotube-containing solutions onto wafer surface, and finally positioning nanotubes at desired locations by magnetically assisted assembly to complete nanotube device structure. The key to this invention is to provide miniature nanotubes with tangible physical properties, in this case, magnetic properties, so that they can be aligned, filtered, and precisely directed to desired locations for device application. Such processes enable nanotubes to be compatible with typical semiconductor wafer processing technologies.